SECTION 506 STEEL BRIDGES

506.1 Description

(1) This section describes fabricating, furnishing, casting, machining or preparing otherwise, delivering, and erecting all the steel and miscellaneous metals required for steel bridges, or metal parts of other bridges.

506.2 Materials

506.2.1 General

(1) Furnish materials conforming to the specifications for the several parts of the completed structure.

506.2.2 Structural Steel

506.2.2.1 General

(1) Furnish structural steel for highway bridges and other structural purposes conforming to the following:

(2) Furnish structural steel for highway structures conforming to the ASTM specifications the plans show. For material that the plans do not indicate the ASTM specifications, furnish structural carbon steel conforming to ASTM A 709 grade 36 (250) as modified in 506.2.2.4.

(3) If the contractor cannot obtain structural carbon steel bar conforming to ASTM A 709 grade 36 (250) for use in secondary members in structures in the quantity for the contract shows, then use one or more of the following alternates:

1. ASTM A 675, grade 60 (415).
2. ASTM A 663, grade 60 (415).

506.2.2.2 Structural Carbon Steel

(1) Use structural carbon steel, 4 inches (100 mm) or less in thickness, conforming to ASTM A 709 grade 36 (250), as modified in 506.2.2.4. For structural carbon steel over 4 inches (100 mm) in thickness, conform to ASTM A 36.

506.2.2.3 High Strength Structural Steel

(1) Use high strength structural steel conforming to ASTM, as modified in 506.2.2.4, as follows:

HSLA columbium-vanadium steels of structural quality:

50 ksi (345 MPa) minimum yield point to 4 inches (100 mm) thick ..... ASTM A 709, grade 50 (345)

HSLA weathering steel:

50 ksi (345 MPa) minimum yield point to 4 inches (100 mm) thick ..... ASTM A 709, grade 50W (345W)

High-yield-strength quenched and tempered alloy steel plate:

Martensitic..... ASTM A 709, grade 100 or 100W (690 or 690W)

Non-martensitic..... ASTM A 709, grade 70W (485W)

506.2.2.4 Charpy V-Notch Requirements

(1) All girder flange plates, girder web plates, flange splice plates, hanger bars, links, rolled beams, flange cover plates, and plates and angles connecting floor beams to girders shall conform to the longitudinal Charpy V-Notch tests specified in ASTM A 709 for zone 2 toughness requirements.

(2) Sample and test according to ASTM A 673. Use the (H) frequency of testing.

506.2.3 Miscellaneous Metals

506.2.3.1 Steel Castings

(1) If using carbon steel castings for bridges and general use, conform to class 70, 90, 120 (485, 620, or 825) of AASHTO M 192 and the following:

1. Furnish the specific class of steel castings the plans show or are specified in the contract.
2. The plans will specify the nondestructive tests to perform and their extent.
3. Use steel castings that are true to pattern in form and dimensions without sharp, unfilleted angles or corners, and free from pouring faults, sponginess, cracks, blow holes, and other defects in positions affecting strength and value for the service intended.

4. If the engineer approves, the contractor may weld defects by an engineer-approved process that does not impair the strength. Remove the defects to solid metal by chipping, drilling, or other satisfactory methods and then weld. If possible, perform this welding before annealing the casting. If the engineer requires, re-anneal any casting welded after annealing.
5. If the engineer requires, the contractor shall test castings by radiography or ultrasonic testing to determine the presence cracks, flaws, or other defects.
6. Ensure that the metal thickness remaining after completing the machining is not less than the thickness the plans show.
7. Thread the ends of the tensile test specimens for at least 3/4 inch (19 mm) with 3/4-inch (19 mm) American N.C. threads.

506.2.3.2 Bronze Castings

(1) If using bronze castings for bearings, trunnions, journals of bridges, and expansion plates, conform to ASTM B 22, alloy No. C91100.

506.2.3.3 Cold-Finished Carbon Steel Shafting

(1) Use cold-finished carbon steel shafting conforming to AASHTO M 169, grades 1016 through 1030. If used for structural pins, then conform to ASTM A 434, grade BC, quenched and tempered.

506.2.3.4 Lubricated Bronze Plates

(1) Fabricate lubricated bronze plates as the plans show and with materials conforming to ASTM B 100, copper alloy No. C51000 or to ASTM B 22, alloy No. C91100.

(2) Provide to the engineer a certified report of test or analysis indicating the manufacturer's test results for the lubricated bronze plates on their chemical and physical properties, including the coefficient of friction of the material used.

(3) Bore or cast the surface of the lubricated bronze plates in a geometric pattern of recesses. Fill the recesses with a lubricating compound consisting of graphite and metallic substances with a lubricating binder capable of withstanding the atmospheric elements. Hydraulically press the compound into the recesses to form dense, non-plastic lubricating inserts. Ensure the lubricated area is within a range of 25 to 33 percent, inclusive, of the bearing face with a coefficient of friction not greater than 0.1. Unless the plans show or the contract directs otherwise, only lubricate the top face of the bronze plate.

506.2.3.5 Steel Forgings

(1) Use steel forgings for pins, rollers, trunnions, and other forged parts conforming to the requirements for class M quenched and tempered forgings of ASTM A 668. Thread the ends of the tensile test specimens for at least 3/4 inch (19 mm) with 3/4-inch (19 mm) American N.C. threads.

506.2.3.6 Welded and Seamless Steel Pipe

(1) Furnish welded and seamless steel pipe for railings and general use conforming to ASTM A 53, type F, or type E, grade B or type S, grade B. Unless provided otherwise, use black, standard weight pipe.

506.2.3.7 Pipe Fittings

(1) Use malleable cast iron or pressed steel pipe fittings for railings and other required uses. If zinc coated fittings are required, the coating shall conform to ASTM A 123.

506.2.3.8 Sheet Lead

(1) Furnish lead in sheet form conforming to ASTM B 29.

(2) Use lead sheets of uniform thickness throughout, free from cracks, seams, slivers, scale, and other surface defects.

(3) Unless the plans show otherwise, use sheet lead 1/8 inch (3 mm) in thickness with a tolerance of +/- 1/32 inch (0.8 mm). Ensure that the length and width are within 1/8 inch (3 mm) of the plan dimensions.

506.2.3.9 Sheet Copper

(1) Furnish strip or sheet copper conforming to ASTM B 152 and suitable for the purpose intended. Unless specified otherwise, use sheet copper with a minimum thickness of 0.02 inch (0.5 mm).

506.2.3.10 Sheet Zinc

(1) For sheet or plate zinc, conform to Prime Western Grade ASTM B 6.

(2) Use sheet and plate zinc of uniform thickness, free from cracks, seams, slivers, scale, surface corrosion, adhering matter, and other surface defects.

(3) Use sheet and plate zinc of the zinc gauge the plans show, with a thickness tolerance of +/- 6 percent. Use sheets that are within 1/8 inch (3 mm) of the length and width the plans show.

506.2.3.11 Welding Materials

(1) Conform to AASHTO/AWS D 1.5, Bridge Welding Code.

506.2.4 Name Plates

506.2.4.1 General

(1) For nameplates installed on bridges and culverts conform to the following requirements.

506.2.4.2 Composition

(1) Provide nameplates made of metal with the following composition by weight:

Copper	84 to 96 percent
Lead	4 to 6 percent
Zinc	4 to 6 percent
Tin	4 to 6 percent
Impurities	Not over 1 percent

(2) Make chemical determinations according to pertinent ASTM standard procedures.

506.2.4.3 Casting

(1) Provide a nameplate cast to conform to dimensions and details the plans show.

(2) Raise the border boss, the boss for anchors and lugs, and raise all lettering and numerals 1/8 inch (3 mm) above the plate face. If attaching the plate by bolts, cast the boss for anchor bolts solid and then drill, but if attaching the plate by lugs, cast the boss and then leave undrilled. Polish the top surface of the border boss, the boss for anchors and lugs, and all lettering and numerals. Make all letters Gothic or block and make square cut on top with sufficient taper to provide the necessary draft to allow removing the mold.

(3) If attaching the plate to metal, attach it to the structure by 2 bolts. Use 1/4-inch (M6) bolts with countersunk metal heads made with the composition specified above for nameplates.

(4) If attaching the plate to concrete, attach it to the structure by 2 lugs at least 3 inches (75 mm) long and cast integral with the nameplate.

506.2.5 High Strength Bolts

506.2.5.1 General

(1) If using high strength bolts in fabricating structural steel rigid joints, conform to AASHTO M 164, unless specified otherwise, and supplement with the following provisions.

(2) The hardness for M12 to M24 bolts inclusive shall conform to the following:

	HARDNESS NUMBER	
BOLT SIZE	BRINELL	ROCKWELL C
	minimum / maximum	minimum / maximum
1/2 to 1 inch (M12 to M24)	248 / 311	24 / 33

(3) If using high-strength bolts, nuts, and washers to fabricate the rigid joints of unpainted, high-strength, low-alloy structural steel conforming to ASTM A 709, grade 50W (345W), use type 3, unless specified otherwise.

(4) For all other high strength bolts, nuts, and washers not encased in concrete, conform to the requirements for Type 1 and ensure they are hot dip zinc coated.

(5) Washers shall conform to AASHTO M 293.

(6) Nuts shall conform to AASHTO M 291 or M 292, as applicable.

(7) Perform hot-dip zinc coating according to ASTM A 153. Instead of hot-dip zinc coating, the contractor may mechanically zinc coat bolts, nuts, and washers according to ASTM B 695, class 50. Remove excess

hot-dip zinc coating on threaded portions by centrifuging or air blasting immediately after withdrawal. The contractor shall not perform flame-chasing.

(8) If hot-dip zinc coating or mechanically zinc coating nuts, use heat-treated ASTM A 194 grade 2H or ASTM A 563 grade DH or DH3.

(9) Use zinc coated nuts that are tapped oversize according to ASTM A 563 and conforming to supplementary requirement S1 of ASTM A 563. Over tap the nut so that the nut assembles freely on the bolt in the coated condition and conforms to the mechanical requirements of AASHTO M 291 and the rotational-capacity test specified in 506.2.5.6.

(10) During field installation, lubricate zinc coated nuts with a lubricant containing dye that contrasts with the color of the zinc coating.

(11) For plain, uncoated nuts use grade 2, C, D or C3 with a minimum Rockwell hardness of 89 HRB or minimum Brinell hardness of 180 HB, or use heat treated grade 2H, DH or DH3.

506.2.5.2 Bolt and Nut Dimensions

(1) Use high strength bolts and nuts conforming to the dimensions the plans show and as specified in AASHTO M 164. Determine the length as specified in 506.2.5.4.

506.2.5.3 Washer Dimensions

(1) Use circular washers that are flat, smooth, and hardened, and conform to the dimensions specified in AASHTO M 164.

(2) Install bolts with a washer under the nut or bolt head, whichever is used in tightening. If the bearing faces of the bolted parts have a slope of more than 1:20 with respect to a plane normal to the bolt axis, use smooth, hardened, and beveled washers to compensate for lack of parallelism.

(3) If clearance is necessary, the contractor may clip washers on one side to a point not closer than 7/8 of the bolt diameter from center of washer.

506.2.5.4 Bolt Lengths

(1) The required bolt length is the grip, total thickness of the connected material, plus the tabulated amount for each bolt size as follows:

BOLT SIZE	AMOUNT ADDED TO THE GRIP
5/8-inch (M16)	1 1/16 inch (27 mm)
3/4-inch (M20)	1 3/16 inch (31 mm)
7/8-inch (M22)	1 5/16 inch (34 mm)
1-inch (M24)	1 9/16 inch (40 mm)
1 1/8 to 1 1/4-inch (M30)	1 13/16 inch (46 mm)
1 3/8 to 1 1/2-inch (M36)	2 1/16 inch (53 mm)

(2) The above values are generalized, with allowance for manufacturing tolerances, to provide for a washer and using a heavy nut, with adequate stick-through at the end of the bolt. For each required beveled washer, add 5/16 inch (8 mm); for any additional washer, add 3/16 inch (5 mm); and for a load-indicating washer, add 1/8 inch (3 mm). Adjust the length determined from the above table increment and allowances for additional washers to the next 1/4 inch (6 mm) length increment for bolts up to 5 inches (125 mm) length and to the next 1/2 inch (13 mm) length increment for lengths over 5 inches (125 mm).

(3) For bolt lengths determined as provided above, the full thread may extend into the grip not more than 3/8 inch (10 mm) for lengths of 5 inches (125 mm) or less, and not more than 5/8 inch (16 mm) for lengths over 5 inches (125 mm).

506.2.5.5 Identification

(1) For high strength bolts, nuts, and washers, provide identification marks specified in ASTM A 325 for the type furnished.

506.2.5.6 Testing and Reporting

(1) Test according to AASHTO M 164, M 291M, M 292 or M 293, as applicable, except that for rotational capacity testing conform to Report No. FHWA SA-91-031 "High Strength Bolts for Bridges".

(2) The contractor shall furnish 2 copies of a certified report of test or analysis indicating the results of required manufacturer/supplier tests as well as documentation verifying the results of additional field testing required under FHWA SA-91-031.

506.2.6 Bearing Pads

506.2.6.1 General

(1) For bearing pads intended for bridge seats use sheet lead or preformed fabric pads or, if designated, elastomeric bearing pads.

(2) Furnish bearing pads conforming to the plan details.

(3) Under the Bearing Pads bid items, if the specific type of bearing pad is not designated, the contractor may furnish either sheet lead or class A preformed fabric pads. Use only one type of bearing pad throughout any one structure unless the plans or the contract provide otherwise.

506.2.6.2 Sheet Lead

(1) Use sheet lead for bearing pads conforming to 506.2.3.8.

506.2.6.3 Preformed Fabric, Class A

(1) This material consists of preformed fabric pads composed of multiple layers of 8-ounce (227 g) cotton duck impregnated and bound with high-quality natural rubber, or of equivalent and equally suitable materials compressed into resilient pads of uniform thickness. The number of plies shall produce the specified thickness after compression and vulcanizing. The finished pads shall withstand compression loads perpendicular to the plane of the laminations of not less than 10,000 pounds per square inch (69 MPa) without harmful extrusion or reduced thickness, under tests conducted according to MIL-C-882E procedures.

506.2.6.4 Non-Laminated Elastomeric

(1) For non-laminated elastomeric bearing pads, use preformed pads, formed by casting or extruding natural rubber or chloroprene under pressure and heat. Cast or extrude the pads in a single, integral layer to the required thickness.

(2) The pads shall conform to the following physical properties:

	NATURAL RUBBER	CHLOROPRENE
Grade (durometer)	60	60
Physical properties		
Hardness (ASTM D 2240)	60±5	60±5
Tensile strength (ASTM D 412)	2500 psi (15.5 MPa)	2500 psi (15.5 MPa)
Ultimate elongation, minimum percent	400	350
Heat resistance, 70 hrs. at 158 F (70 C) (ASTM D 573)		
Hardness, maximum points change	+10	+15
Tensile strength, maximum percent change	-25	-15
Ultimate elongation, maximum percent change	-25	-40
Compression set (ASTM D 395, method B)		
22 hrs. at 158 F (70 C) maximum percent	25	N.A.
22 hrs. at 212 F (100 C) maximum percent	N.A.	35
Ozone (ASTM D 1149), 20 percent strain, 100 ± 2 F (38 ± 1 C)		
mounting procedure ASTM D 518, method A		
25 pphm ozone in air by volume, 48 hrs.	No cracks	N.A.
100 pphm ozone in air by volume, 100 hrs.	N.A.	No cracks

(3) Evaluate the material furnished for acceptance based on the manufacturer's certified report of test or analysis indicating it conforms to these special properties, but the department may obtain test specimens. Before using the material, furnish to the engineer a manufacturer's certified report of test or analysis.

(4) For test specimens, if required, conform to ASTM D 3184 or D 3190, as applicable.

506.2.6.5 Laminated Elastomeric

506.2.6.5.1 General

(1) Use laminated elastomeric bearing pads conforming to 506.2.6.4 and the requirements below.

506.2.6.5.2 Pad Construction

(1) Mold together all components of a laminated bearing into an integral unit and cover all the laminate edges with a minimum of 1/4 inch (6 mm) of elastomer. Seal all cavities left in the edge of the pad by the manufacturing process using heat bonded vulcanized patching.

(2) The contractor may cut all elastomer pads from large sheets of the material cast to the required thickness. Cut the pads in a manner that avoids heating or damaging any material. Produce edges at least as smooth as an ANSI 250 finish (steel mill finish).

(3) Cover the metal reinforcement edges with 1/4 inch (6 mm) of elastomer. Dimension tolerances and configurations shall conform to AASHTO LRFD Bridge Design Specifications, except for the thickness of the elastomer cover over top and bottom steel plates use a tolerance of +/- 1/16 inch (2 mm).

(4) For the internal steel plates use rolled mild steel conforming to ASTM A 36, or ASTM A 570 Grade 36 (250) or higher.

(5) Submit shop drawings conforming to 506.3.2.

(6) Mold the manufacturer's name or trademark into the edge of each laminated bearing pad on a face visible after structure erection.

506.2.6.5.3 Testing

(1) Perform adhesion testing by slitting, on the top or bottom of the bearing pad, approximately a one-inch (25 mm) wide by 4 inch (100 mm) long strip of elastomer. Make the slits the depth of the steel plate. Peel back the strip of elastomer far enough to form a tab that can be gripped with grips approximately one inch (25 mm) from the elastomer-steel interface. Grip the elastomer tab with jaws attached to a load cell and pull at an angle of 90 +/- 2 degree to the steel plate. Measure the adhesion value as the force required to initiate peeling of the elastomer from the steel plate.

(2) The pads shall conform to the following physical properties:

	NATURAL RUBBER	CHLOROPRENE
ADHESION TEST:		
Bond made during vulcanization, ASTM D 429, method B	40 psi (18 kg/25 mm)	40 psi (18 kg/25 mm)
LOW TEMPERATURE TEST:		
Brittleness at –40 F (-40 C), ASTM D746, procedure B	No failure	No failure

(3) The manufacturer shall select a minimum of one bearing pad for each size category of a production run at random for load testing. Load test a minimum of one bearing pad for every 50 bearing pads of a single production run for the project. The manufacturer shall provide bearing pad test data and certification to the contractor at least 30 days before shipping. The manufacturer shall label all test bearing pads and ship to the contractor.

(4) The compressive strain in any layer of an elastomeric bearing pad shall not exceed 7 percent at 800 pounds per square inch (5500 kPa) average unit pressure at 70 F (21 C) under laboratory testing for the full size bearing pad.

(5) Use a compressive load of 1200 pounds per square inch (8300 kPa) for proof load testing. The engineer will reject the bearing pads if bulging patterns imply laminated placement does not satisfy design criteria and manufacturing tolerances, or if bulging suggests inadequate laminate bond. The engineer will also reject the bearing pads if there are 3 separate surface cracks greater than 1/16 inch (2 mm) wide by 1/16 inch (2 mm) deep.

(6) The shear resistance of laminated bearing pads shall not exceed 40 pounds per square inch (275 kPa) for 60 durometer natural rubber or 75 pounds per square inch (517 kPa) for 55 durometer chloroprene compounds at 25 percent strain of the total effective rubber thickness after an extended 4 day ambient temperature of –20 F (-29 C).

(7) The contractor shall assume the cost for bearing pad testing.

506.2.7 Welded Stud Shear Connectors

(1) For shear connector studs conform to ASTM A 108, cold-finished bars, grades 1015, 1018, or 1020, either semi- or fully killed. If using flux-retaining caps, use low carbon grade steel for the caps suitable for welding that comply with ASTM A 109.

(2) Tensile properties, determined testing bar stock after drawing, or of finished studs, shall conform to the following:

Minimum tensile strength.....60 ksi (413.7 MPa)
Minimum yield strength[1].....50 ksi (344.7 MPa)
Minimum elongation..... 20 percent in 2 inches (50 mm)
Minimum reduction of area .....50 percent

[1] As determined by the 0.2 percent offset method.

(3) Determine tensile properties according to ASTM A 370. Perform tensile tests of finished studs on studs welded to test plates using a test fixture similar to figure 7.2 of AASHTO/AWS D 1.5. If fracture occurs outside the middle half of the gauge length, repeat the test.

(4) Ensure that finished studs are of uniform quality and condition, free from injurious laps, fins, seams, cracks, twists, bends, or other injurious defects. Produce the finish by cold drawing, cold rolling, or machining.

(5) The contractor shall not paint or zinc coat studs.

(6) Furnish arc shield (ferrule) of heat-resistant ceramic or other material with each stud that does not damage the welds, or does not cause excessive slag, and will not crumble or break due to thermal or structural shock before completing the weld.

(7) The contractor shall submit the following information on the studs to the engineer for approval before installation:

- The name of the manufacturer.
- A detailed description of the stud and arc shield.
- Documentation that the studs qualify as specified in ANSI/AASHTO/AWS D 1.5.

506.2.8 Bearing Assemblies

506.2.8.1 General

(1) Use bearing assemblies conforming to the material requirements, sizes, and details the plans show.

(2) Blast clean fabricated structural steel bearing components as specified in 506.3.31.3 before zinc coating. After zinc coating, apply a wash primer to the components and the coating system in the color selected for the structural steel under the concrete. If using weathering steel, paint the bearing assemblies with one coat of organic zinc-rich primer and one shop coat of high-build brown epoxy paint. The contractor shall not blast clean, zinc coat, or paint stainless steel and teflon surfaces.

506.2.8.2 Fixed Bearing Assemblies

(1) Zinc coat the complete bearing assembly, including anchor bolts, nuts and washers, but excluding elements welded to the girder. Zinc coat the anchor bolts, nuts, and washers, according to ASTM A 153, class C. Zinc coat the remainder of the assembly according to ASTM A 123.

506.2.8.3 Expansion Bearing Assemblies

(1) An expansion bearing assembly unit consists of a top sole plate, a bottom masonry plate, a rocker plate, a slide plate, side retainers, anchor bolts with nuts and washers, and a lead plate, all as described below and as the plans show.

(2) Zinc coat all structural steel surfaces, including anchor bolts, nuts and washers, that do not come in contact with other structural steel surfaces, or stainless steel, or tetrafluoroethylene (TFE) surfaces, as specified in 506.2.8.2 for fixed bearing assemblies.

(3) For the stainless steel sheet for the top element of sliding bearings use type 304 conforming to ASTM A 240 and ensure it is not less than 1/16 inch (1.6 mm) thick after finishing. Make the finished stainless surface a plane within a tolerance of 1/32 inch (0.8 mm) and with a 2B finish as specified in ASTM A 480.

(4) During welding, protect the surface of the stainless steel plate from weld splatter.

(5) After fabrication, provide a near mirror finish on the surface of the stainless steel plate.

(6) Use TFE materials that are virgin tetrafluoroethylene fluorocarbon resin, unfilled. The finished materials shall exhibit the following physical properties:

REQUIREMENT	TEST METHOD	UNFILLED VALUE
Hardness at 78 F (26 C)	ASTM D 2240 Shore "D"	50-65
Tensile strength, psi (kPa)	ASTM D 1457	2800 (19 300) Min.
Elongation, percent	ASTM D 1457	200 Min.
Deformation under load		
% at 73.4 F (23 C) & 2000 psi (13 800 kPa)	ASTM D 621 method A	15 Max
Specific gravity	ASTM D 1457	2.14 Min.
Melting point	-	623 +/- 2 F (328 C +/-1)

(7) Ensure the finished TFE sheet is not less than 1/16 inch (1.6 mm) or more than 3/32 inch (2.4 mm) thick.

(8) Bond the TFE sheet to the 1/2 inch (13 mm) steel sheet with extreme care using a proven high-temperature-resistant epoxy bonding material. Use a 2-component, medium viscosity epoxy resin conforming to ASTM D 1763 for this purpose.

(9) The engineer may allow welding to steel plate that has a bonded TFE surface provided welding procedures are established that restrict the maximum temperature reached by the bond area to less than 300 F (149 C), use temperature indicating wax pencils or other suitable means to determine temperature.

(10) If epoxy bonding TFE sheets, ensure that one side of the TFE sheet is factory treated by the sodium naphthalene or sodium ammonia process by a department-approved manufacturer.

(11) Perform TFE bonding at the bearing manufacturer’s factory under controlled conditions and according to the engineer-approved adhesive systems manufacturer’s written instructions. The bonding operation should produce a TFE surface that is smooth and free from bubbles.

(12) At installation, ensure the stainless steel sliding face of the upper element and the TFE sliding face of the lower element have the surface finish specified and are clean and free of all dust, dirt, moisture, or any other foreign matter.

506.2.9 Steel Diaphragms

(1) Furnish steel diaphragms conforming to the plan details.

506.2.10 Zinc Coated Fabrication

(1) Conform to ASTM 385 for fabricating zinc coated work.

506.2.11 Accepting Secondary Fabrication Items by Certification

(1) Contractors shall obtain all bridge metal secondary fabrication items from fabricators whose products conform to the department's certification method of acceptance for bridge metal secondary items, unless the engineer agrees to accept these items according to the alternate procedures set forth in the department's certification acceptance procedures. Secondary fabrication items are defined as:

- Rail posts
- Anchor assemblies for rail posts
- Plates
- Sleeves
- Shims
- Rail panels
- Anchor bolts
- Protection angles
- Structural fasteners
- Expansion devices
- Curb and sidewalk cover
- Floor drains
- Guard rail anchors
- Sheet lead
- Elastomeric pads
- Bearing assemblies (steel)
- Structural steel diaphragms

506.3 Construction

506.3.1 General

(1) This work includes everything reasonably considered necessary for a complete and finished job according to the plans and contract.

(2) Provide a quality and finish equal to the best general practice in modern bridge shops. Neatly finish all portions of the work exposed to view. Perform shearing, flame cutting, and chipping, carefully and

accurately. For members requiring Charpy V-Notch testing, the contractor shall not cut by shearing or full-size hole punching.

506.3.2 Shop Drawings

(1) Shop drawings shall conform to the contract plans and consist of shop detail, erection and other working plans or computations showing dimensions, sizes of material, including the dimensional properties of all rolled shapes, details and other information necessary for completely fabricating and erecting metal work. Each sheet of the shop drawings shall carry the project and the structure numbers.

(2) The contractor shall submit to the engineer, for placing on file before commencing fabrication, one set of shop drawings that the contractor has checked. In addition, provide 2 sets to the region office and one set to the bureau of structures for inspection purposes. Only then may fabrication commence without awaiting the results of any review the engineer may make. The engineer may refuse prints of shop drawings that are not clear and legible. If the engineer requests, submit one additional copy of drawings for review. After review, the contractor shall furnish as many copies of shop drawings as required.

(3) The shop drawings become a part of the contract, provided any differences between sections on shop drawings and sections the plans show are made only if the engineer approves and if the substitution is made at no additional expense to the department.

(4) After initial submittal and review, make no deviation from the shop drawings or changes to them without the engineer’s further review.

(5) The engineer's review of shop drawings means only a review of the character and sufficiency of the details and does not relieve the contractor from responsibility in regard to errors or omissions on those drawings.

(6) Ensure that the fabricator, upon completing contracts involving structures supporting railroads, delivers to the railroad company 3 sets of shop drawings of the structures.

506.3.3 Structural Steel Identification

(1) In addition to ordinary mill identification, paint the appropriate color, according to ASTM A 6, on all structural steel, except steel conforming to ASTM A 709, grade 36 (250) without toughness requirements, on each end of each piece before shipment from the mill. Before working any piece in the shop, move the identifying paint marks a sufficient distance away from the end to ensure the identity of the piece during fabrication. Mark angles on the inside of a leg. Mark beams and channels on the inside of a flange. Paint the ends of pieces if assembly will destroy or make identification by the above methods impossible. If the contractor fails to exercise the above precautions, the engineer will reject the piece.

506.3.4 Rolled Material

506.3.4.1 Straightening

(1) Ensure rolled material is straight before being laid off or worked. If straightening is necessary, perform it without injuring the metal. The engineer may reject material with sharp kinks and bends.

506.3.4.2 Camber

(1) If the plans show, camber all rolled beams. The camber shall conform to a uniform, approximately circular curve for the entire length of the beam or between designated points. Ensure the designated camber is within the tolerance specified in the American Institute of Steel Construction Manual. The steel manufacturer may produce camber, or produce or correct it by local heating. If the plans show camber less than the minimum camber likely to remain permanent as tabulated in the Manual of Steel Construction of the American Institute of Steel Construction, produce the camber by applying heat.

(2) If cambering beams or correcting camber by local heating, take care not to overheat the metal. The contractor shall not heat the metal above 1200 F (649 C). Select the areas to heat so that no distortion other than the required camber occurs. Follow a procedure that prevents beam flange warpage.

(3) Support the beam near its ends facing the side made concave upward. Apply propane, natural gas, or other engineer-approved gas flame to areas selected so that no distortion other than the required camber occurs. Apply heat by playing the flame over the section until the metal attains a maximum temperature of 1000 F to 1200 F (538 C to 649 C). Control the temperature by using temperature- indicating crayons, liquids, or bimetal thermometers. Notify the engineer before applying any heat.

(4) Heat the areas in generally wedge- or triangular-shaped areas with an included angle between 10 and 20 degrees. Locate the vertex of the angle on the web midway between flanges. Slowly play the flame over

the area heated, commencing at the vertex of the angle and finishing at the widest part of the heated wedge, extending across the flange width. Manipulate the torch, or torches, to rapidly bring the total area heated to the proper temperature at the same time.

(5) Space the heated sections to produce uniform curvature. Heat no less than 3 sections, and it may require heating additional sections if the beam is unusually long or heavily cambered. Do not use water to cool the metal, or heat any area more than once. Air cool the heated metal slowly away from wind or drafts. The engineer may reject the beam if improper heating or cooling occurs that might affect the strength or ductility of the metal.

506.3.5 Bolt Holes

(1) Punch or drill all holes for bolts. The contractor may punch bolt holes 1/16 inch (2 mm) larger than the nominal diameter of the bolts in material forming a member made of no more than 5 metal thicknesses and if the metal is not thicker than 3/4 inch (19 mm) for structural carbon steel, 5/8 inch (16 mm) for high strength structural steel, or 1/2 inch (13 mm) for quenched and tempered alloy steel. For more than 5 thicknesses, or if the main material is thicker than 3/4 inch (19 mm) for structural carbon steel, 5/8 inch (16 mm) for high strength structural steel, 1/2 inch (13 mm) for quenched and tempered alloy steel, or if required otherwise, subpunch, or subdrill all holes 3/16 inch (5 mm) smaller. After assembling, ream them 1/16 inch (2 mm) larger or drill from the solid to 1/16 inch (2 mm) larger than the nominal diameter of the bolts. The contractor may use oversized holes in secondary members if the engineer allows.

(2) The die diameter shall not exceed the punch diameter by more than 1/16 inch (2 mm). If enlarging holes to admit the bolts, then ream the holes. Ensure clean-cut holes without torn or ragged edges. The engineer may reject poorly matched holes.

(3) Make reamed or drilled holes cylindrical, perpendicular to the member and not more than 1/16 inch (2 mm) larger than the nominal diameter of the bolts. If possible, direct the reamers by mechanical means. Remove burrs on the outside surfaces. Poor matching of holes shall be cause for rejection. Perform reaming with tapered reamers. If removing burrs caused by drilling, take apart the assembled parts. For connecting parts that require reamed or drilled holes, assemble them first and then hold securely during reaming or drilling.

506.3.6 Accuracy of Holes

506.3.6.1 Punched and Drilled Holes

(1) Ensure that all holes punched full size, subpunched, or subdrilled are so accurate that after assembling (before performing reaming) a cylindrical pin 1/8 inch (3 mm) smaller in diameter than that of the punched hole can enter it, without drifting, in at least 75 percent of the contiguous holes in the same plane. Failure to conform to this requirement will result in rejection of the badly punched pieces. In addition, the engineer will reject any hole that will not pass a pin 3/16 inch (5 mm) smaller in diameter than that of the punched hole.

506.3.6.2 Reamed and Drilled Holes

(1) If holes are reamed or drilled, 85 percent of the holes in any contiguous group shall, after reaming or drilling, show no offset greater than 1/32 inch (1 mm) between adjacent thicknesses of metal.

(2) Use steel templates that have hardened steel bushings in the holes, and are accurately dimensioned from the connection centerlines as inscribed on the template. Use the centerlines to accurately locate the template from the milled or scribed ends of the members.

506.3.7 Shop Assembly

506.3.7.1 General

(1) Unless specified otherwise, subpunch or subdrill, and ream while shop assembled bolt holes in connections and splices (shop and field) of main truss or arch members, continuous beams, floor beam connections to girder or truss, continuous plate girders, and rigid frames; or drill them full size from the solid while assembled at the shop. Subpunch or subdrill floor beam connections for plate girders and trusses and ream or drill full size from the solid in assembly. The contractor may use engineer-approved alternate procedures.

(2) Unless the engineer authorizes otherwise, assemble each individual truss, arch, continuous beam, or girder full length at the shop before reaming or drilling. Obtain approval of other than full-length assembly before submitting the shop drawings and show the engineer-approved alternate assembly procedure shall on the shop drawings. During shop assembly, support all members in a manner that does not cause

undesirable deflections. The inspector will approve assembly, including camber, alignment, accuracy of holes, and milled joints, before drilling or reaming.

(3) Conform to 506.3.27 for pickup points and girder handling equipment.

(4) Ensure that the component parts of a built-up member are straight and close fitting. Matchmark all the members and all parts of the built-up members before disassembling.

506.3.7.2 Fitting for Bolting

(1) Clean the metal surfaces in contact with other each other before assembling. Before drilling, reaming, or bolting, assemble the parts of a member, pin, and draw together. Take apart the assembled pieces in order to remove the burrs and shavings this operation produces. Ensure the member is free from twists, bends, and other deformation.

(2) During assembly tolerate only the drifting necessary to bring the parts into position and not sufficient to enlarge the holes or distort the metal.

506.3.8 Flame Cutting

(1) The contractor may flame cut structural steel, provided this process produces a smooth surface free from cracks and notches and a mechanical guide is used to produce an accurate profile. The engineer must approve hand cutting.

(2) Flame cut plates in a direction that allows the stress in the plate, when assembled, to be parallel to the direction the plate was rolled.

(3) Ensure that flame cutting is adjusted and manipulated to cut within the prescribed lines. Flame cut surfaces shall conform to the ANSI surface roughness value of 1000 for material up to 4 inches (100 mm) thick and 1600 for material 4 to 8 inches (100 to 200 mm) thick, except that the ends of members not subject to calculated stress at the ends shall have a surface roughness value of 2000. Round the corners of flame cut surfaces of members that carry calculated stress to approximately a 1/16-inch (2 mm) radius by grinding after flame cutting.

(4) Cut re-entrant cuts to a radius of not less than one inch (25 mm).

(5) Remove surface roughness exceeding the above values and occasional gouges not more than 3/16 inch (5 mm) deep on otherwise satisfactory flame cut surfaces by machining or grinding. Correct defects by flairing into the cut surface on a slope of at least 1 to 10. Repair gouges of flame cut edges more than 3/16 inch (5 mm) deep but not more than 7/16 inch (11 mm) deep by welding, if the engineer approves, with low-hydrogen electrodes not exceeding 5/32 inch (4 mm) in diameter and with a preheat of 250 F (121 C). Grind the completed weld smooth and flush with the adjacent surface.

506.3.9 Edge Planing

(1) Plane the sheared edge of plates more than 5/8-inch (16 mm) thick and carrying calculated stress to a depth of 1/4 inch (6 mm).

506.3.10 Connections

(1) Unless specified otherwise, make all connections with M 20 high strength bolts conforming to ASTM A 325.

506.3.11 (Vacant)

506.3.12 Bolts and Bolted Connections

506.3.12.1 General

(1) Furnish sufficient bolts of each type, size, and length required with an ample surplus to replace those lost or rejected.

(2) Perform shop assembly and matchmarking as specified in 506.3.7.

(3) If assembled, ensure all joint surfaces, including those adjacent to washers, are free of scale, dirt, oil, burrs, pits, and other defects that prevent solid seating of the parts.

506.3.12.2 Unfinished Bolts

(1) If using unfinished bolts for temporary connections and other specifically allowed uses, use standard bolts with hexagon heads and nuts. Ensure the bolt hole diameters are 1/16 inch (2 mm) greater than that of the bolt.

(2) Thread bolts transmitting shear so that not more than one thread is within the grip of the metal. Use lock washers under the nuts for unfinished bolts used in permanent connections.

506.3.12.3 High Strength Bolts

(1) Install bolts according to AASHTO Standard Specifications for Highway Bridges Division II, Article 11.5.6.4, with the following exceptions:

1. If connections are assembled, install bolts with a hardened washer under the nut or bolt head, whichever is the element turned in tightening.
2. If using oversized holes, 2 hardened washers are required, one under the bolt head and one under the nut.
3. Bring the bolted parts into solid contact bearing before final tightening. Use not less than 25 percent of the total number of bolts in a joint to serve as fitting up bolts.

(2) The contractor may use a flat washer if the surface adjacent to and abutting the bolt head or nut does not have a slope of more than 1:20 with respect to a plane normal to the bolt axis. For slopes greater than 1:20, use smooth, beveled washers to produce parallelism.

(3) Tighten each fastener to provide, if all fasteners in the joint are tight, at least the minimum bolt tension as follows:

TABLE 506-1 BOLT TENSION

BOLT SIZE	REQUIRED MINIMUM BOLT TENSION[1]
1/2-inch	12 050 pounds
5/8-inch	19 200 pounds
3/4-inch	28 400 pounds
7/8-inch	39 250 pounds
1-inch	51 500 pounds
1 1/8-inch	56 450 pounds
1 1/4 inch	71 700 pounds
1 3/8-inch	84 450 pounds
1 1/2-inch	104 000 pounds

[1] Equal to the proof load by the length measurement method as specified in ASTM 325 or ASTM 325M for metric bolts.

(4) Tighten threaded bolts by the turn-of-nut method or by the load-indicator- washer method. If required, because of bolt entering and wrench operations clearances, the contractor may tighten by either procedure by turning the bolt while preventing the nut from rotating.

(5) The contractor may propose an alternate tightening method but the engineer must approve it before use.

(6) During installation, regardless of the tightening method used, exercise care to achieve the “snug tight” condition defined in AASHTO Standard Specifications for Highway Bridges Division II, Article 11.5.6.4.4.

(7) Do not reuse zinc coated M 164 bolts. The contractor may reuse other M 164 bolts, if the engineer approves, but not more than once. The department will not consider re-tightening previously tightened bolts that become loosened by the tightening of adjacent bolts as reuse.

(8) Perform the rotational-capacity test on each rotational-capacity lot before beginning bolt installation. Hardened steel washers are required as part of the test although the actual installation procedures may not require them.

(9) Provide and use a Skidmore-Wilhelm Calibrator or an acceptable equivalent tension measuring device at each job site during erection. The contractor may test bolts that are too short for the Skidmore-Wilhelm Calibrator by using direct tension indicators calibrated in the Skidmore-Wilhelm Calibrator using longer bolts. Provide the engineer with 2 copies of the test results.

(10) Install bolt, nut, and washer (if required) combinations from the same rotational-capacity lot.

(11) Check zinc coated nuts to verify that a visible lubricant is on the threads.

(12) Ensure that plain, uncoated bolts are oily to the touch over their entire surface when delivered and installed.

(13) Clean and re-lubricate weathered or rusted bolts or nuts not conforming to the requirements above before installation. Retest all re-cleaned or re-lubricated bolt, nut, and washer assemblies before installation.

506.3.12.3.1 Turn-of-Nut Method

(1) If using the turn-of-nut method to provide the bolt tension specified in table 506-1, first ensure that enough bolts are "snug tight" to insure the parts are in full contact with each other. Snug tight is defined as the tightness attained by a few impacts of an impact wrench or the full effort of a person using an ordinary spud wrench. Following this operation, place bolts in any remaining holes in the connection and bring them to snug tightness. Then tighten all bolts in the joint by the amount of nut rotation specified in table 506-2 proceed tightening from the most rigid part of the joint to its free edges. During this operation, ensure the part not turned by the wrench does not rotate.

TABLE 506-2 NUT ROTATION FROM SNUG TIGHT CONDITION[1]

	DISPOSITION OF OUTER FACES OF BOLTED PARTS		
Bolt length measured from underside of head to extreme end of point	Both faces normal to bolt axis	One face normal to bolt axis and other face sloped not more than 1:20 (bevel washer not used)	Both faces sloped not more than 1:20 from normal to bolt axis (bevel washers not used)
Up to and including 4 diameters	1/3 turn	1/2 turn	2/3 turn
Over 4 diameters but not exceeding 8 diameters	1/2 turn	2/3 turn	5/6 turn
Over 8 diameters but not exceeding 12 diameters[2]	2/3 turn	5/6 turn	1 turn

[1] Nut rotation is relative to bolt regardless of the element, nut or bolt, being turned. For bolts installed by 1/2 turn and less, the tolerance should be +/- 30 degrees; for bolts installed by 2/3 turn and more, the tolerance should be +/- 45 degrees.

[2] No research work has been performed by the Research Council on Riveted and Bolted Structural Joints to establish the turn-of-nut procedure when bolt lengths exceed 12 diameters. Therefore, determine the required rotation by actual tests in a suitable tension device simulating the actual conditions.

506.3.12.3.2 Load-Indicator-Washer Method

(1) If using the load- indicator-washer method to provide the bolt tension specified in 506.3.12.3(3), place an engineer-approved load indicator washer on the bolt with the protrusions facing away from the connected materials. Place a hardened washer under the element, nut or bolt head, turned in tightening. If required to use the tension indicator under the turned element, fit the hardened washer against the protrusions of the load indicator washer.

(2) Reduce the average gap between the face of the indicator and the underside, washer face of the bolt to the minimum gap specified by the manufacturer to produce the required bolt tension. If the indicator washer is in place under the turned element, reduce the average gap between the indicator and the hardened washer according to the manufacturer's recommendations to provide the correct tension. During the operation, ensure no rotation of the part not turned by the wrench.

(3) Check the gaps on a minimum of 25 percent of the bolts with a metal feeler gauge and according to the gaps the manufacturer recommends for the tension required. Inspect the first bolts used to bring the joint in contact to ensure no loosening occurred during the complete tightening procedure. The contractor may restore the tension on these bolts by tightening to less than the original. If the gap between the indicator and washer or bolt head is completely closed on a bolt, discontinue tightening s to prevent breakage.

506.3.12.3.3 Inspection

506.3.12.3.3.1 General

(1) Perform all specification requirements for bolt connections to the engineer’s satisfaction.

(2) The procedure for bolt installation shall meet the engineer's approval.

(3) Use the following inspection unless a more extensive or different inspection procedure is specified.

506.3.12.3.3.2 Turn-of-Nut Method

(1) Either the engineer or the contractor in the presence of the engineer, at the engineer's option, shall use a manual torque inspection wrench accurately calibrated as follows:

(2) Place 3 bolts of the same grade, size, length, and condition as those being inspected, individually in a bolt tension calibration device (furnished by the contractor). Place a washer under the part turned in tightening each bolt. Tighten each bolt in the calibration device by any convenient means to the minimum tension specified for its size in 506.3.12.3. Then apply the inspecting wrench to the tightened bolt and determine the torque necessary to turn the nut or head 5 degrees, which is approximately one inch (25 mm) at a 12 inch (300 mm) radius, in the tightening direction. Use the average torque measured in the tests of 3 bolts as the job inspecting torque and use in the manner specified below.

(3) Inspect the bolts represented by the sample described above that were tightened in the structure by applying, in the tightening direction, the inspecting wrench and its job inspecting torque to 10 percent of the bolts, but not less than 2 bolts, selected randomly in each connection. If this process does not turn any nut or bolt head then the engineer will accept the connection as properly tightened. If this process does turn any nut or bolt then apply this torque to all bolts in the connection, and re-tighten and re-inspect all bolts whose nut or head turns, or the fabricator or erector has the option of re-tightening all bolts in the connection and then resubmitting the connection for the specified inspection.

506.3.12.3.3.3 Load-Indicator-Washer Method

(1) If using load-indicator-washers, the engineer will witness use of the metal feeler gauge during installation.

(2) Inspect load-indicator-washers by using a metal feeler gauge instead of a calibrated inspecting wrench. After completing the bolted connection, the engineer will inspect by using a metal feeler gauge on a minimum of 10 percent of the bolts, but not less than 2 bolts, selected randomly in each connection. If all gaps inspected are within the allowable gaps, the engineer will accept the connection as properly tightened. If any gaps checked are in excess of the recommended gap, the fabricator or erector shall re-inspect and re-tighten, as required, each bolt in the assembly and resubmit the connection for inspection.

506.3.13 Abutting Joints

(1) Mill or saw cut abutting joints in compression members of trusses and in columns to give a true and square cut.

(2) Openings at abutting joints in tension members in continuous I-beams and plate girders shall not exceed 3/8 inch (10 mm).

506.3.14 Facing of Bearing Surfaces

(1) Make the top and bottom surfaces of steel slabs and the base plate and cap plates of columns and pedestals straight, smooth, and free from warp and must bear evenly throughout.

(2) If necessary, plane the bases of welded steel bearings after welding to secure an even bearing.

(3) Plane the bases of cast steel bearings after annealing to secure an even bearing.

(4) Ensure that the sole plates of beams and girders have full contact with the flanges, and that the bearing surface is smooth, true, and perpendicular to the web of the member. Ensure that curved sole plates make full line bearing with masonry or bearing plates, and that the line is at right angles to the axis of the member and perpendicular to the web of the member unless the plans show otherwise.

(5) If planning the curved surfaces of expansion bearings, operate the tool so that the cut is in the expansion direction. If the cut of the tool is at right angles, make the finished surface the true arc of a circle, smooth and free from ridges.

(6) Finish contact steel surfaces subject to sliding motion in the direction of motion as specified in ANSI No. 125.

(7) Machine finish all surfaces that the plans show to receive a surface finish.

(8) Polish finish the surfaces of bronze bearing plates intended for sliding contact.

(9) If using lubricated bronze plates, cover the finished surface of the expansion plate assembly in contact with the lubricated bronze plate with a plastic or other engineer-approved coating after machining. Before erecting the girder, remove this coating and coat the surface with graphite.

506.3.15 Web and Flange Plates

(1) At bolted splices, the clearance between the ends of the web and flange plates shall not exceed 3/8 inch (10 mm).

(2) If the plans show camber for welded girders, produce the camber by machine flame cutting the web plate. Cut all cambers on a continuous smooth curve. If the engineer approves, correct moderate deviations from specified camber by a carefully supervised application of heat.

(3) For welded girders, if detailed to a horizontal curve greater than 3 degrees, cut the flange plates to a continuous smooth curve by machine flame cutting. If the curve is 3 degrees or less, curve the girder by either heat curving methods that the engineer approves, unless the plans specify otherwise. The contractor may curve the girder by machine flame cutting.

(4) Assemble the web and flange plates in the work so that the direction of stress in the plate, as assembled, is parallel with the direction that the plate was rolled.

506.3.16 Fit of Stiffeners

(1) Ensure that the end stiffeners of girders and stiffeners intended as supports for concentrated loads bear fully on the flanges that they transmit load to or from which they receive load. Obtain full bearing by milling, or grinding, or in the case of weldable steel in compression areas, by welding as the plans show or as specified.

(2) If the clearance between the end of the stiffener and the flange for stiffeners is not intended to support concentrated loads, then the gap shall not exceed 1/16 inch (2 mm) unless the plans show or the contract specifies otherwise.

506.3.17 Pin and Roller Details

506.3.17.1 Pins and Rollers

(1) Turn pins and rollers to the dimensions the plans show and make them straight, smooth, and free from flaws.

(2) Forge and anneal pins and rollers that are more than 9 inches (229 mm) in diameter. For pins and rollers 9 inches (229 mm) or less in diameter use either forged and annealed or cold-finished, carbon-steel shafting.

(3) In pins larger than 9 inches (229 mm) in diameter, bore a hole, not less than 2 inches (50 mm) in diameter and full length along the axis after the forging cools below the critical range under conditions suitable to prevent injury by too rapid cooling and before annealing.

(4) Use standard recessed pin nuts for nuts in connection with pins.

506.3.17.2 Pinholes

(1) Bore pinholes true to the specified diameter, smooth, straight, at right angles with the axis of the member, and parallel with each other unless required otherwise. Produce the final surface s by using a finishing cut.

(2) The pinhole diameter for pins without bushings shall not exceed the pin diameter by more than 1/50 inch (0.5 mm) for pins 5 inches (127 mm) or less in diameter, or 1/32 inch (0.8 mm) for larger pins. For pins with bushings, follow the manufacturer’s recommendations for tolerances of pins and bushings.

506.3.17.3 Threads for Bolts and Pins

(1) Threads for all bolts and pins for structural steel construction shall conform to the Unified Standard Series UNC-ANSI B1.1, Class 2A for external threads and Class 2B for internal threads, except that pin ends with a diameter of 1 3/8 inch (35 mm) or more shall have 6 threads per one inch (25 mm).

506.3.18 Finished Members

(1) Make finished members true to line and ensure they are free from twists, bends, and open joints.

506.3.19 Welding

506.3.19.1 General

(1) Welding of steel structures shall conform to these specifications and to ANSI/AASHTO/AWS D 1.5, Bridge Welding Code.

(2) Furnish welders or welding operators certified to the requirements of ANSI/AASHTO/AWS D 1.5. If the engineer questions a welder or welding operator's ability, requalification tests are required under

ANSI/AASHTO/AWS D 1.5, paragraphs 5.31 and 5.42. A department-approved independent testing agency will perform requalification testing.

506.3.19.2 Welding Procedures, Procedure Qualifications and Inspection

506.3.19.2.1 Procedures

(1) Submit the proposed complete welding procedures to the engineer in triplicate for approval before fabricating the structural steel.

(2) The welding procedures include, but are not limited to, the following items:

1. General instructions for fit-up, techniques, and welding sequences.
2. Types of steel, joint description, joint preparation, preheat or post-heat, and welding position.
3. Current polarity, amperage, wire speed, voltage, and linear welding speed.
4. Electrode size and type for manual welding.
5. Electrode size and AWS classification for automatic and semi-automatic welding.
6. Classification of flux; number of passes, any procedure change between passes in the same weld.
7. Any other data necessary to fully describe the welding procedure.

(3) Use engineer-approved submerged arc automatic welding processes for all primary shop welds. Use an automatic welding process that uses mechanically controlled wire or electrode feed, speed of travel, and guidance. Noncompliance with this requirement is cause to reject the welded material unless the engineer grants prior approval to weld the specified joints by other processes. Show the automatic welding process requirement for primary shop welds on the shop drawings for each joint. Primary shop welds are defined as flange and butt welded splices in I-beams, box members and plate girders; plate girder or box flange to web groove and fillet welds; and cover plate to flange fillet welds.

(4) Do not use electroslag or electrogas weld.

(5) Grind all flange butt welds. Grind web butt welds as follows: 1/6 of the web depth beginning at the point of maximum tension,1/6 of the web depth beginning at the point of maximum compression and the entire outside surface of exterior girders. Ground all surfaces that require grinding before performing radiographic or ultrasonic inspection. Grind plates with a surface or surfaces in the same plane flush. Grind plates with surfaces not in the same plane smooth.

(6) Ensure that weld metal for fillet and groove welds for exposed, bare, unpainted applications of ASTM A 709 grade 50 (345) steel possess similar atmospheric corrosion resistance and the same coloring characteristics as that of the base metal.

506.3.19.2.2 Procedure Qualifications

(1) Procedure qualifications shall conform to Section 5 of ANSI/AASHTO/AWS D 1.5.

(2) The contractor shall complete qualification tests of the welding procedures and obtain the engineer's acceptance of them before beginning steel fabrication. Submit any revisions in the welding procedure specifications to the engineer for approval and qualify them in the presence of the State's inspector to qualify for acceptance.

(3) Before the starting qualifying welding procedures, the contractor and the State's inspector shall confer to ensure reaching an agreement regarding the procedure details, the welding sequence, the handling of materials to be inspected, the status of welders and welding inspectors qualifications, and the approval of electrodes, wire, flux, and other welding materials and equipment.

(4) Assign each welder or welding operator an identification mark for them to paint on the pieces welded. The welder or welding operator shall use these identification marks for the duration of the contract.

506.3.19.2.3 Inspection

(1) Inspect welding according to ANSI/AASHTO/AWS D 1.5. Unless specified otherwise, test butt welds in main members by either the radiographic or the ultrasonic method.

(2) Test fillet welds and groove welds not covered otherwise in main members in a non-destructive manner by the magnetic particle method according to ASTM E 709, utilizing the yoke method. This includes, but is not limited to, a minimum of 12 inches (300 mm) in every 10 feet (3 m) or portion thereof of each weld connecting web to flange, bearing stiffener to web or flange, framing connection bar to web or flange, and longitudinal stiffener to web or vertical bar.

506.3.20 Stud Shear Connectors

(1) Use studs for shear connectors if the plans show. Weld according to 506.3.19 and the following requirements. If conflicts occur, the following requirements shall govern:

(2) Fillet welds varying in size from 3/16 inch to 5/16 inch (5 mm to 8 mm) are satisfactory provided the studs pass all other required tests. Make adequate provision in structural member fabrication to compensate for camber loss due to shear connector welding.

(3) Ensure the studs are free from rust, scale, rust pits, and oil at the time of welding and immediately before placing the concrete.

(4) Longitudinal and lateral spacing of studs with respect to each other and to edges of beam or girder flanges shall not vary more than 1/2 inch (13 mm) from the dimensions the plans show, except that the engineer will allow a variation of one inch (25 mm) if required to avoid obstruction of other attachments on the beam, or if welding a new stud to replace a defective one. Ensure a minimum distance from the edge of a stud shank to the edge of a beam or plate of one inch (25 mm) exists, but preferably 1 1/2 inch (38 mm) or more.

(5) Inform the engineer promptly of any changes in the welding procedure at any time during construction.

(6) If welding the studs reduces their height to less than normal, immediately stop welding and do not resume until correcting the cause.

(7) After welding the studs to the beams, perform a visual inspection and give each stud a light blow with a hammer. Strike with a hammer and bend 15 degrees from the correct installation axis Any stud: without a 360-degree end weld, that does not ring if given a light blow with a hammer, repaired by welding, or that is reduced to less than normal in height due to welding. In cases of a defective or a repaired weld, bend the stud 15 degrees in the direction that places the weld’s defective portion in the greatest tension. Replace studs that crack either in the weld or in the shank.

(8) The engineer may select additional studs to subject to the bend test specified above.

506.3.21 Mill Inspection and Tests

(1) Unless directed otherwise, the fabricator of structural steel shall furnish the engineer with 2 copies of a certified report of test or analysis showing both physical and chemical tests of the material for each heat of material. Submit these inspection and test reports to the inspector for examination and before requesting the fabrication shop inspection or when requesting the material prepayment inspection. The engineer will not approve prepayment for material that mill test reports are not submitted.

506.3.22 Shop Inspection

(1) The engineer may inspect all structural steel and miscellaneous metals furnished.

(2) Give the engineer ample notice of the beginning of the shop work.

(3) Before requesting an inspector, the fabricator shall submit a list of main stress-carrying members and the heat number of the material from which fabricating the member. Preserve the heat number, as marked by the rolling mill, for identification by the inspector. If fabrication hides, cuts off, or obliterates otherwise the original number or marking, the fabricator shall paint the number on the material at a conspicuous location.

(4) Furnish facilities in the shop for inspecting material and work quality and allow the inspectors necessary access to all parts of the work. The facilities shall include adequate office space at the fabricating plant for the inspector's use during fabrication, assembly, cleaning, and painting. At the plants of all major fabricators, as the engineer determines, ensure this office space has at least 100 square feet (9.3 m^2) of floor space and is furnished with at least 2 desks, or a desk and table, a file case, and other necessary furniture. Provide adequate lighting, heating, and ventilation and ensure cleanliness. Provide office space that is a completely partitioned area separated from the fabricator's activities, has a separate door equipped with a suitable lock and key; or is part of a larger facility set aside for the exclusive use of outside inspection personnel. Make available telephone service and adequate sanitary facilities in the immediate area. The engineer may revise the foregoing requirements to accommodate the number of inspectors necessary to inspect the volume of work.

(5) The inspector may reject any material or work that does not conform to the specification requirements.

(6) The inspector’s acceptance of any material or finished members will not preclude their subsequent rejection if found defective.

(7) Inspection at the shop is intended as a means of facilitating the work and avoiding error. It shall not relieve the contractor of responsibility for imperfect material, or technique, or for replacing the same.

506.3.23 Marking and Shipping

(1) Paint or mark each member with an erection mark for identification and furnish an erection diagram showing the erection marks. Mark members weighing more than 3 tons (3 Mg) with their weight. Load structural members on trucks or cars in a manner that transports and unloads them at their destination without being excessively stressed, deformed, or damaged otherwise. Ship all girders and rolled beams in a standing position, maintain this position in subsequent operations. The fabricator may ship haunched sections of built-up girders in an inverted position.

(2) Ship high strength bolts, nuts, and washers (if required) from each rotational-capacity lot in the same container. If there is only one production lot number for each size of nut and washer, the supplier may ship the nuts and washers. Pack separately non-high-strength bolts of one length and diameter, and the loose nuts and washers supplied for each size of bolt, except ship zinc coated bolts, nuts, and washers of the same size in the same containers. Ship bolts, nuts, washers, pins, and small parts in boxes, crates, kegs, or barrels, but the gross weight of any container shall not exceed 300 pounds (136 kg). Clearly and permanently, mark a list on the outside of each shipping container that describes the contained material. Clearly and permanently, mark on the outside of each shipping container of bolts, nuts and washers the rotational-capacity lot number, in addition to a list and description of the contained material.

506.3.24 Handling and Storing

(1) Place material to be stored on skids above the ground. Keep it clean and properly drained. Place girders and beams upright, shore, and tie or brace to preclude tipping or overturning if exposed to high winds. Support long members, such as columns and chords, on skids placed near enough together to prevent injury from deflection. Loss of any material, or any damage caused after receiving it is the contractor’s responsibility.

(2) Store bolts, nuts, and washers in original containers and protect them from dirt and moisture until used.

506.3.25 Field Inspection

(1) Erections are subject to inspection and the contractor shall furnish facilities for inspection of material and work quality. The inspector will inspect material and work quality not previously inspected after its delivery to the work site.

506.3.26 Falsework

(1) The contractor may furnish previously used materials for falsework. Ensure proper design, construction, and maintenance of falsework in order to handle the loads placed upon it. Falsework shall provide the required construction camber.

(2) Submit detailed plans for falsework to the engineer if requested. The engineer's approval of these plans, or acceptance in work constructed according to them shall not relieve the contractor of responsibility for successful erection or satisfactory results.

(3) If building falsework over a stream or lake subject to boating use, construct it to provide horizontal and vertical clearance adequate for passage of rowboats and small powerboats. If building falsework over a highway or street used by traffic provide a minimum clearance, unless the plans or special provisions require otherwise, of 22 feet (6.71 m) horizontal and 13 feet 6 inches (4.12 m) vertical.

(4) After completing the work, remove falsework piles down to at least 2 feet (600 mm) below streambed or finished ground line. Remove entirely any temporary bents, mudsills, and footings.

(5) Do not attach overhang bracket form supports to the girder web.

506.3.27 Erection

(1) Do not apply any part of the steel superstructure load to any concrete substructure unit until the concrete in that unit cures for at least 48 hours under favorable conditions. Do not apply loads to beams of open-type structure units until the end of the required period for falsework support of these beams.

(2) Unless specified otherwise the minimum number of pickup points are as follows:

GIRDER LENGTH	MINIMUM NUMBER OF PICKUPS
0-50 feet (0-15 m)	1
50 feet and over (15 m and over)	2 or more

(3) Use an appropriate balance beam or spreader bar for 2 or more pickup points with a single crane. Locate pickup points to avoid damage to the girder and to balance the load at each point.

(4) The contractor shall not place any bent or twisted member until correcting its defects. The engineer will reject any members seriously damaged in handling or transporting.

506.3.28 Straightening Bent Material

(1) Perform straightening of plates and angles or other shapes by methods not likely to produce fracture or other injury. Unless the engineer allows, do not heat the metal; if the engineer does allow, then do not heat to a temperature higher than 1200 F (649 C) (a dull red) and the operation by temperature-indicating crayons, liquids, or bimetal thermometers.

(2) Ensure that parts to be heat straightened are substantially free of stress and external forces, except for stresses resulting from mechanical means used in the application of heat. After heating, cool the metal as slowly as possible away from drafts. Do not use water for cooling.

(3) After straightening a bend or buckle, inspect the metal surface carefully for evidence of fracture.

506.3.29 Field Assembling and Bolting

(1) Conform to the foregoing requirements for shop assembling. Make field connections, unless specified otherwise, with high strength bolts as specified in 506.3.12.

(2) Unless the engineer allows, do not use a burning torch to make adjustments or cuts as an aid to field assembling.

(3) Before beginning the field bolting on a continuous span, adjust the span and the immediately adjacent continuous spans to the correct grade, construction camber, and alignment.

(4) Complete field bolting, except for compression joints in trusses, connections for laterals and railings, and connections for those nominal members the plans or contract specifically designates, before releasing and swinging free any part of the span from its supporting falsework.

(5) Swing the span free from falsework before making connections for laterals.

(6) After placing and curing the concrete floor, and sidewalks if any, on all spans of the structure, make the connections for those nominal members as the plans show or the contract specifically designates. Erect, align, and fasten the railings in place.

(7) For splices and field connections using high strength bolts, fill at least 25 percent of the holes with cylindrical erection pins before placing the permanent high-strength bolts. Fill at least 25 percent of the holes with erection bolts for temporary connections. Place all bolts before proceeding with final tightening as specified in 506.3.12.

(8) Ensure that erection bolts are the same nominal diameter as the high strength bolts and that cylindrical erection pins are 1/32 inch (0.8 mm larger).

(9) The contractor may assemble girders or portions of girders or other units on cribbing to the required blocking before erection or placement in the structure, if the engineer approves. Any necessary adjustments in the joints or splices of the assembled units after erection or placement are the contractor’s responsibility.

506.3.30 Bearings and Anchorage

(1) Do not place masonry bearing plates on bridge seat bearing areas that are improperly finished, deformed, or irregular.

(2) Set the bearing plates level in exact position and have full and even bearing on the masonry. Unless required otherwise, place them on bearing pads conforming to 506.2.6.

(3) After properly aligning and finally connecting the steel in the superstructure, drill the holes in the concrete and set the anchor bolts except if the bolts are built into the masonry.

(4) Set anchor bolts in an engineer-approved, premixed, non-shrink commercial grout, except during freezing weather, or in an epoxy conforming to 415.2.6. Place the grout according to the manufacturer's instructions and fill the hole before ramming the bolt in place. Overfill the hole with just enough grout or epoxy to produce a watertight fit when the bearing plate is installed. Remove excess grout or epoxy from the bolt and bearing area.

506.3.31 Cleaning of Surfaces

506.3.31.1 General

(1) Blast clean the surfaces of all structural steel to remove rust, mill scale, dirt, oil, or grease and other foreign substances until obtaining the specified finish.

(2) Blast clean all non-machined surfaces of a casting before machining the casting.

506.3.31.2 Coated Surfaces

(1) As specified in 506.3.32, blast clean all structural steel and all ferrous metal products to be coated as specified for blast cleaning in 517.3.1.3.3 to a near-white finish according to SSPC-SP 10. Blast clean steel that will be encased in concrete to SSPC-SP 6 standards or cleaner.

506.3.31.3 Unpainted Weathering Steel

(1) Blast clean all surfaces of weathering steel, unless designated for coating, until obtaining a finish as described for commercial blast cleaning in SSPC-SP 6. Perform blast cleaning with sand, grit or steel shot as described for SSPC-SP 6.

(2) Keep or place the following markings on material shipped to the field:

- Weights of members weighing 3 tons (3 Mg) or more.
- Piece marks.
- Matchmarks if required.

(3) Place weight markings on interior surfaces of exterior girders and on interior girders in locations that are inconspicuous after erection and their removal are not required except if the engineer directs.

(4) After erection, clean all steel in the completed structure by hand, until free of oil, dirt, grease, mortar and other foreign substances.

506.3.32 Painting Metal

(1) Unless the contract provides otherwise, apply 3 coats of paint to all structural steel and ferrous metal products. Furnish and apply paints according to the epoxy system or as specified in the special provisions. The requirements for this system are set forth in section 517.

(2) For structural steel, including weathering steel, and miscellaneous metals that will be encased in concrete, paint as specified in 517.3.1.

(3) Apply one coat of organic zinc-rich primer and one shop coat of high-build epoxy paint to the end 6 feet (1.8 m) of all structural weathering steel at the abutments, the 6 feet (1.8 m) on each side of piers, joints, downspouts, and hinges excluding the exterior faces of the exterior girders, and zinc-coated bearings in contact with weathering steel. Use a brown colored high-build epoxy coat. Apply one coat of zinc-rich paint to surfaces of expansion joint assemblies and other surfaces not in contact with the weathering steel but inaccessible after assembly or erection.

(4) Do not paint structural steel to be welded before completing welding. If welding only in the fabricating shop and subsequently erecting by bolting, coat it after completing shop welding. Apply one coat of weldable primer or other engineer-approved protective coating to steel surfaces to be field welded after completing shop welding and shop fabrication. Protect machine-finished surfaces that do not receive a paint or zinc coating from contamination during the cleaning and painting process.

(5) Upon fabrication and acceptance, coat pins and pinholes with a plastic or other engineer-approved coating before removing from the shop.

(6) Mark members weighing 3 tons (3 Mg) or more with their weights on areas that will be encased in concrete, or paint with a compatible paint on zinc-rich primer, or mark with soapstone on an epoxy-coated surface. Wait until material is dry, inspected and approved for shipment before loading for shipment.

506.3.33 Name Plates

(1) Furnish and install nameplates conforming to 506.2.4.

(2) Furnish and place one nameplate on each structure at the location the plans show.

(3) If attaching nameplates to the structure steel, attach it with of 2 bolts conforming to the requirements of 506.2.4. If required to attach the plate to concrete, attach it as specified in 502.3.11.

(4) No permanent plates or markers, other than the above designated nameplate and specified benchmarks, are allowed on any structure, unless the engineer approves otherwise.

506.3.34 Steel Diaphragms

(1) Install steel diaphragms as the plans show.

506.4 Measurement

(1) The department will measure Structural Steel Carbon, Structural Steel HS, the Castings bid items, Forgings Steel Carbon, Lubricated Plates Bronze, and the Sheet bid items by the pound acceptably completed based on plan quantities the department-approved bridge plans show.

(2) The department will use the following unit weights to compute the weight of metals:

MATERIAL	UNIT WEIGHT
Steel: structural carbon, high strength structural, castings, or forgings	490 lb/ft^3 (7849 kg/m^3)
Bronze plate and castings	536 lb/ft^3 (8586 kg/m^3)
Sheet copper 0.02 inches (0.5 mm) thick	0.93 lb/ft^2 (4.54 kg/m^2)
Sheet zinc No. 12 zinc gauge, 0.028-inch (0.71 mm)	1.05 lb/ft^2 (5.13 kg/m^2)
Sheet zinc No. 18 zinc gauge, 0.055-inch (1.40 mm)	2.06 lb/ft^2 (10.06 kg/m^2)
Sheet zinc No. 20 zinc gauge, 0.070-inch (1.78 mm)	2.62 lb/ft^2 (12.79 kg/m^2)

(3) Compute the weights of all rolled shapes based on their nominal weights and dimensions. Compute the weights of all plates, including those of zinc and copper based on their nominal weights and dimensions and make full deduction for all cuts except interior cuts, beveled cuts on edges for butt welding, and cuts made by machining to provide other than plane surfaces.

(4) The department will not include the weight of paint, zinc coating, or weld metal in the computed weight.

(5) The department will include the weight of heads, nuts, single washers, and threaded stick-through of all high strength bolts and heads, based on the following weights:

BOLT DIAMETER	WEIGHT PER 100 BOLTS
1/2-inch	19.7 pounds
5/8-inch	31.7 pounds
3/4-inch	52.4 pounds
7/8-inch	80.4 pounds
1-inch	116.7 pounds
1 1/8-inch	165.1 pounds
1 1/4-inch	212.0 pounds
METRIC BOLT SIZE	MASS PER 100 BOLTS
M16	14.6 kg
M20	26.2 kg
M22	38.1 kg
M24	47.3 kg
M27	66.9 kg
M30	86.0 kg

(6) The department will not measure load indicator washers for payment.

(7) Compute the weight of castings from their dimensions and add 3 percent for fillets and overruns, however, if the scale weight of any casting is less than the computed weight, the department will pay for the weight of that casting at the scale weight. If the scale weight of any casting is less than 97 percent of the computed weight, the department may reject the casting.

(8) If the computed weights of metals, from engineer-approved shop drawings, varies more than one percent from those the engineer-approved bridge plans show for an individual structure, the department will base quantities for that structure on those computed from the engineer-approved shop drawings. The exception is if the contractor elects, with the engineer's permission, to use equivalent sections of greater weight than those the engineer-approved bridge plans show, then the contractor shall bear all additional costs.

(9) The department will measure Bearing Pads by the square foot acceptably completed.

(10) The department will measure Bearing Pads Elastomeric Non-laminated and Bearing Pads Elastomeric Laminated as each individual pad acceptably completed.

(11) The department will measure the Welded Stud Shear Connectors bid items as each individual unit acceptably completed. The department will measure the total number of connectors incorporated in the work and accepted.

(12) The department will measure the Steel Diaphragms bid items as each individual diaphragm acceptably completed.

(13) The department will measure the Bearing Assemblies bid items as each individual unit acceptably completed. The department will measure the total number of assemblies incorporated in the work and accepted.

506.5 Payment

(1) The department will pay for measured quantities at the contract unit price under the following bid items:

ITEM NUMBER	DESCRIPTION	UNIT
506.0105	Structural Steel Carbon	LB
506.0605	Structural Steel HS	LB
506.1000 - 1099	Castings (type)	LB
506.1105	Forgings Steel Carbon	LB
506.1405	Lubricated Plates Bronze	LB
506.1500 - 1599	Sheet (type)	LB
506.2105	Bearing Pads	SF
506.2605	Bearing Pads Elastomeric Non-Laminated	EACH
506.2610	Bearing Pads Elastomeric Laminated	EACH
506.3000 - 3099	Welded Stud Shear Connectors (7/8 x inch)	EACH
506.4000	Steel Diaphragms (structure)	EACH
506.5000	Bearing Assemblies Fixed (structure)	EACH
506.6000	Bearing Assemblies Expansion (structure)	EACH

(2) Payment for Structural Steel Carbon, Structural Steel HS, the Castings bid items, Forgings Steel Carbon, Lubricated Plates Bronze, and the Sheet bid items is full compensation for providing, fabricating, casting, machining or otherwise preparing, transporting, and erecting all materials; for providing name plates; and for furnishing radiographic films to the inspector.

(3) Payment for Bearing Pads is full compensation for providing and placing the pads.

(4) Payment for Bearing Pads Elastomeric Non-Laminated and Bearing Pads Elastomeric Laminated is full compensation for providing the pads, and for testing, if required.

(5) Payment for the Welded Stud Shear Connectors bid items is full compensation for providing the shear connectors.

(6) Payment for the Bearing Assemblies bid items is full compensation for providing bearing assemblies, including the anchor bolts, and for fabricating and installing the assemblies.

(7) Payment for the Steel Diaphragms bid items is full compensation for providing, fabricating, zinc coating, transporting, and erecting.

(8) The contractor shall perform miscellaneous work that the plans show or is specified otherwise and included within the scope of this contract but not listed as bid items as a part of and included in the contract price for other bid items, except as follows:

- If the contract does not contain the Welded Stud Shear Connectors, Bearing Assemblies Fixed, or Bearing Assemblies Expansion bid item, and the contract requires this work, the department will pay for this work as Structural Steel Carbon.
- The department will pay for painting structural steel and miscellaneous metals as specified in 517.5.